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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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METHOD AND APPARATUS FOR DIGITAL WATERMARKING, AND STORAGE MEDIUM STORING DITITAL WATERMARK PROCESSING PROGRAM

[Claims]

1. A method for embedding digital watermark data in digital data contents by means of quantized value, said method comprising the steps of:

inputting a partial data of the digital data contents and complexity of the partial data of the digital data contents;

changing data changing amount of the quantization within the quantized value according to the complexity of the partial data of the digital data contents;

changing the partial data value; and

outputting the partial data of the digital data contents embedded with the digital watermark data.

2. The method as claimed in claim 1, further comprising the steps of:

applying wavelet transform to the partial data of the digital data contents;

filtering the value of the high frequency component data by means of a threshold value; and

calculating a complexity of the partial data of the digital information contents from numbers that are above the threshold value.

3. A method for embedding digital watermark data in digital data contents, said method comprising the steps of:

inputting a partial data of the digital data contents;

calculating a changed amount of frequency component based on the changed amount of every frequency range by means of the changed amount of the every frequency range according to editing method of the digital data contents; and

outputting the partial data of the digital data contents embedded in the digital watermark data.

4. A method for reading digital watermark data from a digital data contents which includes the watermark, said method comprising the steps of:

inputting the partial data of the digital data contents which includes the watermark; and

reading and outputting the digital watermark data from the frequency component based on the changed amount of every frequency range by use of the changed amount of

the every frequency range according to an editing method of the digital data contents.

5. A method for converting digital data contents to frequency component and perform digital watermark processing to the frequency component, said method comprising the steps of:

inputting the second partial data which edit one or more digital data contents by means of the first partial data of one or more digital data contents and the expected editing method of the digital data contents,

transforming said first partial data and said second partial data into the frequency component by applying orthogonal transform which is used when applying the digital watermark processing to the digital data contents;

calculating a standard deviation of distribution of said difference values of the data of every first and second frequency component; and

applying the digital watermark by multiplying a watermark embedding strength as the changed amount of each frequency component.

6. The method for embedding digital watermark data as claimed in claim 1, further comprising the steps

of:

calculating quantized value, which is used for the digital watermark embedding, by means of the changed amount of every frequency range according to the editing method of the digital data contents; and

changing the partial data value based on said value and the complexity of the partial data.

7. An apparatus for embedding digital watermark data in digital data contents, said apparatus comprising:

a function for inputting a partial data of the digital data contents and complexity of the partial data of the digital data contents;

a function for changing data changing amount of the quantization within the quantized value according to the complexity of the partial data of the digital data contents;

a function for changing the partial data value; and

a function for outputting the partial data of the digital data contents embedded with the digital watermark data.

8. The apparatus for embedding digital watermark data, said apparatus further comprising:

a function for applying wavelet transform to the partial data of the digital data contents;

a function for filtering the value of the high frequency component data by means of a threshold value; and

a function for calculating a complexity of the partial data of the digital information contents from numbers that are above the threshold value.

9. The apparatus for embedding digital watermark data in the digital data contents, said apparatus further comprising:

a function for inputting a partial data of the digital data contents;

a function for calculating a changed amount of frequency component based on the changed amount of every frequency range by means of the changed amount of the every frequency range according to editing method of the digital data contents; and

a function for outputting the partial data of the digital data contents embedded in the digital watermark data.

10. The apparatus for embedding digital watermark data in the digital data contents, said

apparatus further comprising:

a function for inputting the partial data of the digital data contents which includes the watermark; and

a function for reading and outputting the digital watermark data from the frequency component based on the changed amount of every frequency range by use of the changed amount of the every frequency range according to an editing method of the digital data contents.

11. An apparatus for converting digital data contents to frequency component and perform digital watermark processing to the frequency component, said method comprising the steps of:

a function for inputting the second partial data which edit one or more digital data contents by means of the first partial data of one or more digital data contents and the expected editing method of the digital data contents,

a function for transforming said first partial data and said second partial data into the frequency component by applying orthogonal transform which is used when applying the digital watermark processing to the digital data contents;

a function for calculating a standard deviation of distribution of said difference values of the data of

every first and second frequency component; and

a function for applying the digital watermark by multiplying a watermark embedding strength as the changed amount of each frequency component.

12. The apparatus for embedding digital watermark data in digital data contents as claimed in claim 7, said apparatus further comprising:

a function for calculating quantized value, which is used for the digital watermark embedding, by means of the changed amount of every frequency range according to the editing method of the digital data contents; and

a function for changing the partial data value based on said value and the complexity of the partial data.

13. A computer readable medium storing program code for causing a computer system to embed digital watermark data in digital data contents, said computer readable medium comprising:

a process for inputting a partial data of the digital data contents and complexity of the partial data of the digital data contents;

a process for changing data changing amount of the quantization within the quantized value according to the

complexity of the partial data of the digital data contents;

a process for changing the partial data value; and

a process for outputting the partial data of the digital data contents embedded with the digital watermark data.

14. The computer readable medium as claimed in claim 13 further comprising:

a process for inputting the partial data of the digital information contents;

a process for applying wavelet transform to the partial data of the digital data contents;

a process for filtering the value of the high frequency component data by means of a threshold value; and

a process for calculating a complexity of the partial data of the digital information contents from numbers that are above the threshold value.

15. A computer readable medium for embedding digital watermark data in the digital data contents, said computer readable medium comprising:

a process for inputting a partial data of the digital data contents;

a process for calculating a changed amount of frequency component based on the changed amount of every frequency range by means of the changed amount of the every frequency range according to editing method of the digital data contents; and

a process for outputting the partial data of the digital data contents embedded in the digital watermark data.

16. A computer readable medium for reading digital watermark data from the digital data contents, said computer readable medium comprising:

a process for inputting the partial data of the digital data contents which includes the watermark; and

a process for reading and outputting the digital watermark data from the frequency component based on the changed amount of every frequency range by use of the changed amount of the every frequency range according to an editing method of the digital data contents.

17. A computer readable medium for converting digital data contents to frequency component and perform digital watermark processing to the frequency component, said method comprising the steps of:

a process for inputting the second partial data

which edit one or more digital data contents by means of the first partial data of one or more digital data contents and the expected editing method of the digital data contents,

a process for transforming said first partial data and said second partial data into the frequency component by applying orthogonal transform which is used when applying the digital watermark processing to the digital data contents;

a process for calculating a standard deviation of distribution of said difference values of the data of every first and second frequency component; and

a process for applying the digital watermark by multiplying a watermark embedding strength as the changed amount of each frequency component.

18. The computer readable medium as claimed in claim 13, further comprising

a process for calculating quantized value, which is used for the digital watermark embedding, by means of the changed amount of every frequency range according to the editing method of the digital data contents; and

a process for changing the partial data value based on said value and the complexity of the partial data.

[Detailed Description of the Invention]

[Field of the Invention]

The present invention relates to a digital watermarking technique for embedding or reading digital watermark data in digital data contents which represent an image or a sound.

[Prior Art]

It is easy to replicate or tamper fraudulently with multimedia production, and the easiness hinders an data content provider from sending data. In addition, some users may not use the data originated from the provider validly. Therefore, copyright protection is strongly needed for the multimedia production. The digital watermarking technique is effective in realizing the copyright protection. According to the digital watermarking technique, sub-data is embedded in data contents without being noticed by a user by utilizing redundancy of data such as of an image and a sound. The digital watermarking technique is used for protecting a multimedia copyright by embedding copyright information, a user ID and the like as the sub-data in secret, since it is difficult to separate the sub-data from the data contents.

Other conventional techniques are proposed in Japanese patent applications No.10-150517, No.10-210427,

No.10-257300, or and No.10-304323.

[Object of the Invention]

The digital watermark method is also called data hiding, finger printing steganography, image/sound deep encryption and the like.

Elements for determining performance of the digital watermarking technique are as follows:

(1) quality of data contents in which the digital watermark is embedded;

(2) durability of the digital watermark which is embedded in the data contents when the data contents are manipulated;

(3) safety against intentional erasing of and tampering with digital watermark data, and

(4) reliability of the digital watermark data which is read from the data contents.

The digital watermarking technique is broadly divided into two methods. One method of gives meaning to a data value by quantizing. For example, by dividing a data value by a quantization value and dividing the result by 2, a bit data can be represented by the remainder. Another method embeds digital watermark data by using a spread spectrum method.

The above-mentioned examples are based on the

former method. In terms of the method, there is a problem with respect to the above element (1) in that the digital watermark data embedded in the data contents may be perceived, or commercial value of the data contents may be lost by embedding the digital watermark data. With respect to the above element (2), the digital watermark data which is embedded in the data contents may be dissipated even when a general user uses the data contents in a normal way. Particularly, it is a difficult problem to achieve both elements (1) and (2) with enough performance in practical use.

It is an object of the present invention to improve quality of watermarked digital data contents and to improve durability of digital watermark data against media processing of the watermarked digital data contents.

[Means to Solve the Problems]

In order to accomplish quality improvements of the data contents embedded with the digital watermark, the present invention calculates a complexity of data based on human perception of each partial data in a process for embedding the digital watermark respectively to the partial data of the data contents, and changes the changed amount of the partial data according to its values. That is, the present invention realizes the

digital watermark by utilizing local data complexity of the data contents which can commensurate with human perception characteristics.

Also, in order to accomplish durability of the digital watermark with regard to the media editing process of the data contents embedded with the digital watermark, in a processing for embedding the digital watermark by changing values of the frequency component, the present invention changes the changed amount in every frequency component to be embedding target. Watermark strength matrix is prepared in every frequency range, and together with this and the digital watermark strength being multiplied will be the frequency component changing amount when actually embedding the digital watermark. With regard to the ratio of the changed amount of each of the every frequency range, by a usage (contents editing) method of the data contents presumed, various original data contents (prepare sufficient contents such as images for the images and audios for the audios) are edited, distribution of the changed amount of the frequency component of before and after the editing took place is determined with each coefficient value, and a standard deviation of the distribution is used.

According to the above-mentioned inventions,

the amount of transformation of frequency coefficients is changed and/or the amount of transformation is increased or decreased according to the complexity of the digital data contents. Therefore, the quality of the watermarked digital data contents can be improved and the durability of digital watermark data against a manipulation of the watermarked digital data contents can be improved.

[Embodiments of the Invention]

Embodiment 1

Fig.1 is a block diagram showing input data and output data of the digital watermark embedding apparatus of the present invention. The digital watermark embedding apparatus 10 inputs digital data contents 103 such as an image and a sound as main data, key data 12 and digital watermark data 101 as sub-data. The digital watermark embedding apparatus 10 embeds digital watermark data 101 into the digital data contents 103 and outputs watermarked digital data contents 104.

Fig.2 is a block diagram showing input data and output data of the digital watermark reading apparatus of the present invention. The digital watermark reading apparatus 20 inputs the watermarked digital data contents 21 and the key data 22, and

outputs digital watermark data 23 embedded in the watermarked digital data contents 21. Here, the key data 22 is the same as the key data 12.

In the following, embodiments of the present invention will be described.

[First Embodiment]

This embodiment is a method for embedding digital watermark data in digital data contents by means of quantized value, said method comprising the steps of:

inputting a partial data of the digital data contents and complexity of the partial data of the digital data contents;

changing data changing amount of the quantization within the quantized value according to the complexity of the partial data of the digital data contents;

changing the partial data value; and

outputting the partial data of the digital data contents embedded with the digital watermark data.

First, digital watermark embedding method based on quantization will be described, and then the improvement of the embodiment is described.

Fig.3 is a flowchart showing the process of the prior art.

The digital watermark embedding apparatus 10 obtains block data 109 by dividing digital data contents

103 into a plurality of blocks (m blocks in this example) in step 100. Then, a frequency coefficient matrix 115(an orthogonal transform coefficient matrix) is generated by performing an orthogonal transform on the block data 108 in step 110. A pseudo-random sequence 125 is generated from input key data 12 in step 120. Then, a coefficient (for each block) from the coefficient matrix 115 is selected one by one using the pseudo-random sequence 125 so as to generate a frequency coefficient sequence 135 to be watermarked in step 130. Each bit of the digital watermark data 101 are diffused by repeating number (t) of embedding so that a digital watermark sequence 145 is generated in step 140. The digital watermark sequence 145 is embedded into the frequency coefficient sequence 135 such that a watermarked frequency coefficient sequence 155 is generated in step 150. After that, the frequency coefficient sequence 135 in the frequency coefficient matrix 115 is replaced by the watermarked frequency coefficient sequence 155 to generate a watermarked frequency coefficient matrix 165 in step 160. Then, the watermarked frequency coefficient matrix 165 is inverse-orthogonal-transformed to form a watermarked block data 175 in step 170. After that, the block data part of the input digital data contents 103 is replaced by the

watermarked block data 175 in step 180. As a result, a watermarked digital data contents is output.

In the following, the watermark embedding process (step 150) will be described in detail with reference to a flowchart shown in Fig.4.

Let the repeating number t of each bit of the digital watermark data be $t=\left\lfloor \frac{m}{n} \right\rfloor$, the frequency sequence be w[j],s[j][k]∈{0,1} {0≦j<n,0≦k<t}.

The watermark embedding process to the frequency sequence {f[i]} is carried out as follows.

1. Following steps are carried out for all i ($0 \le i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n$).

2. A watermarked frequency coefficient f'[i] is obtained from the frequency coefficient f[i] according to following steps.

i) If $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor \bmod 2$ is equal to s[X][Y],

$$f'[i] \leftarrow \left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor \times q .$$

ii) If $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor \bmod 2$ is different from s[X][Y] and $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor$ is equal to $\left\lfloor \frac{f[i]}{q} \right\rfloor$,

$$f'[i] \leftarrow \left(\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor + 1\right) \times q .$$

iii) If $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor \bmod 2$ is different from s[X][Y] and $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor$ is different from $\left\lfloor \frac{f[i]}{q} \right\rfloor$,

$$f'[i] \leftarrow \left(\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor - 1\right) \times q .$$

Here, X=i/t and $Y = i \bmod t$. In addition, $\lfloor x \rfloor$ represents a maximum number which does not exceed x and x mod y represents the remainder of x divided by y.

Fig.5 shows the concept of the conventional watermark embedding process. As shown in the figure, digital watermark data is embedded by changing a data value of watermarking area to a central value of the quantization width.

Fig.9 is a flowchart of the whole process of the first embodiment. In Fig.9, a step 190 which calculates the complexity and a watermark embedding process for varying the transformation amount according to the complexity (steps 195, 150) are different from the conventional process shown in Fig.2. Therefore, the different point will be mainly described in the following.

Block data 105 is input, and a complexity

sequence 195 is generated by calculating a data complexity $e[i] (0 \leqq e[i] \leqq 1)$ for each block data in step 190. Then, the coefficient value of data to be watermarked is transformed to a value within quantization width according to the data complexity. In this embodiment, it is possible to use a conventional method for calculating the data complexity. For example, in the case of an image, a process for obtaining local image complexity can be used. In this case, it is necessary to normalize the range of the local complexity such that the range becomes from 0 to 1, if the range is from $-\alpha$ to $+\beta$.

Next, the watermark embedding process which is the heart of the second embodiment will be described in detail. Fig.7 is a flowchart showing the watermark embedding process (step 150) in detail.

The process for embedding digital watermark data into a frequency coefficient sequence {f[i]} of the first embodiment is carried out as follows.

1. For all i $(0 \leq i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n)$, the following process is carried out.

2. A watermarked coefficient f'[i] is obtained from a coefficient f[i].

i) If $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor \bmod 2$ is equal to s[X][Y],

$$f'[i] \leftarrow f[i] + \left(\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor \times q - f[i] \right) \times e[i]$$

ii) If $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor \bmod 2$ is not equal to s[X][Y] and $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor$ is equal to $\left\lfloor \frac{f[i]}{q} \right\rfloor$,

$$f'[i] \leftarrow \left(\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor + \frac{e[i]+1}{2} \right) \times q$$

iii) If $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor \bmod 2$ is not equal to s[X][Y] and $\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor$ is not equal to $\left\lfloor \frac{f[i]}{q} \right\rfloor$,

$$f'[i] \leftarrow \left(\left\lfloor \frac{f[i]}{q} + \frac{1}{2} \right\rfloor - \frac{e[i]+1}{2} \right) \times q .$$

Here, q represents the quantization width for digital watermark data embedding, X=i/j,Y=imodt, and $\lfloor x \rfloor$ is the maximum integer which does not exceed x, and x mod y represents the remainder of x divided by y.

Fig.8 is conceptual diagrams showing the digital watermark embedding process of the first embodiment. As shown in Fig.8, a data complexity e[i] (0 ≦e[i]≦1) is calculated for each block data, then, the value of data in which digital watermark data is

embedded is transformed to a value within the quantization width according to the data complexity.

Generally, the quality of the watermarked digital data contents is a trade-off for the strength of the digital watermark data. However, according to the present invention, both of the quality of the watermarked digital data contents and the watermark durability can be improved while keeping the quality and the durability in balance. That is, digital watermark data is embedded according to the local data complexity. Specifically, digital watermark data is embedded with a greater strength in a complex part, and is embedded with a weaker strength in a non-complex part.

The watermarking technique has an embedding process and a reading process in a pair. However, even if the embedding process is modified from the conventional process according to the present invention, the reading process does not need to be changed from the conventional reading process for reading the digital watermark data which is embedded by the method of the present invention.

[Second Embodiment]

In the following, a second embodiment of the present invention will be described. The second embodiment relates to the process for calculating the

data complexity (step 190 in Fig.6). According to the second embodiment, the block data is transformed by applying Wavelet transform. Then, high frequency coefficient data of the wavelet transformed data is filtered by using a threshold value, and the complexity of the block data is calculated from the number of the data values which exceed the threshold.

Fig.9 is a flowchart of the process for calculating the data complexity according to the second embodiment. Here, let the dimension of a block data B[i] be N, and let the size of the block data be $M_0 \times M_1 \cdots \times M_{N-1}$. A following process is performed on each element $h_{v0,v1,\cdots,vN-1}$ $(0<v_u<M_u/2,\ 0<u<N)$ of the high frequency coefficient matrix $H_0 \times H_1 \cdots \times H_{N-1}$ of N dimensional wavelet transformed block data.

1. count$\leftarrow$0

2. For all $(v_0, v_1, \cdots, v_{N-1})$, a step 3 is carried out (N dimensional loop).

3. For a threshold $\Delta \geqq 0$ which is set beforehand, If $|h v_0, v_1, \cdots, v_{N-1}| \geqq \Delta$, count$\leftarrow$count$+1$. Here, $|x|$ represents the absolute value of x.

4. For a threshold $\Gamma \geqq 0$ which is set beforehand, If count$\geqq \Gamma$, e[i]$\leftarrow$1.0. If not, e[i]$\leftarrow \frac{count}{\Gamma}$.

In the process for calculating the data

complexity, for example, if it is assumed that N=2 (an image), the basis of the wavelet transform is the Haar basis, $M_0=16$ and $M_1=16$, an experiment shows that values of $\Delta=4$ and $\Gamma=16$ are good for the balance for embedding digital watermark data without being notified by a human.

According to the second embodiment, the above-mentioned function can be realized by setting the two thresholds Δ and Γ according to the characteristics of the watermarking technique such as the kind of data to be watermarked, a unit (the size of the block data), the kind of orthogonal transform to be used. By applying the above-mentioned function to the watermarking technique, it becomes possible to embed digital watermark data more appropriately according to characteristics of individual digital data contents.

(Third Embodiment)

In the following, a fourth embodiment of the present invention will be described.

According to the third embodiment, in the digital watermark embedding process, block data of digital data contents is obtained, and a transformation amount of frequency coefficient is calculated on the basis of a transformation amount for each frequency band according to a manipulation method of the digital data contents. Then, block data of the watermarked digital

data contents is generated.

Let the dimension of a block data B[i] be N and the size be $M_0 \times M_1 \cdots \times M_{N-1}$. Here, a sequence which represents the ratio of transformation width for the frequency band of each frequency coefficient needs to be obtained beforehand by using adequate digital data contents before operating a digital watermarking system. The calculation method for obtaining q[i] will be described in detail in a fifth embodiment later.

Fig.10 is a flowchart for obtaining the ratio of the quantization with for each frequency band. First, digital data contents 1000 is input, and block data 1015 is obtained by dividing the input digital data contents into blocks in step 1010. The block data 1015 is transformed to first frequency coefficient matrices by applying the orthogonal transform in step 1020. Next, digital data contents 1035 is generated by performing a manipulation such as non-reversible compression on the digital data contents 1000 in step 1030. Then, block data 1045 is generated by dividing the digital data contents 1035 into blocks in step 1040. Second frequency matrices 1055 is generated by applying the orthogonal transform to the block data 1015 in step 1055. Then, the variance of the distribution of the difference between each element of the frequency coefficients

matrices 1025 and each element of the frequency coefficients matrices 1055 is obtained in step 1060. Finally, watermark weight ratio data $d_{v_0,v_1,\cdots,v_{N-1}}$ 1070 which represents the ratio of transformation for each frequency coefficient is obtained. The watermark weight ratio data obtained in this way is stored, and it is used in a watermark embedding process and a watermark reading process as necessary. The quantization width is obtained as $d_{v_0,v_1,\cdots,v_{N-1}} \times$ Power which will be described next.

Fig.11 is a flowchart showing the watermark embedding process which is the heart of the third embodiment of the present invention. Here, the flow of the whole process is the same as that shown in Fig.3 or Fig.6.

Let the watermark weight ratio sequence be $\{d_{v_0,v_1,\cdots,v_{N-1}}\}$ $(0 \leqq v_u < M_u, 0 \leqq u < N)$, and let the watermark strength be Power (the watermark strength represents durability of digital watermark data against manipulations of watermarked digital data contents.)

The watermark embedding process of the embodiment is carried out as follows.

1. For all i $\left(0 \le i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n\right)$, a following process is carried out.

2. A quantization width q[i] used when embedding digital watermark data into the frequency coefficient f[i] is obtained by $q[i] \leftarrow d_{v_0,v_1,\cdots,v_{N-1}} \times Power$ by using an element $d_{v_0,v_1,\cdots,v_{N-1}}$ of the watermark weight ratio sequence which corresponds to the band of the frequency coefficient f[i] (f[i] is a $(v_0,v_1,\cdots,v_{N-1})$ th component of the frequency coefficient matrices).

3. The watermarked frequency coefficient f'[i] is obtained from the frequency coefficient f[i] in the following way.

i) If $\left\lfloor \frac{f[i]}{q[i]} + \frac{1}{2} \right\rfloor \bmod 2$ is equal to s[X][Y],

$$f'[i] \leftarrow \left\lfloor \frac{f[i]}{q[i]} + \frac{1}{2} \right\rfloor \times q[i].$$

ii) If $\left\lfloor \frac{f[i]}{q[i]} + \frac{1}{2} \right\rfloor \bmod 2$ is not equal to s[X][Y] and $\left\lfloor \frac{f[i]}{q[i]} + \frac{1}{2} \right\rfloor$ is equal to $\left\lfloor \frac{f[i]}{q[i]} \right\rfloor$,

$$f'[i] \leftarrow \left(\left\lfloor \frac{f[i]}{q[i]} + \frac{1}{2} \right\rfloor + 1 \right) \times q[i]$$

iii) If $\left\lfloor \frac{f[i]}{q[i]} + \frac{1}{2} \right\rfloor \bmod 2$ is not equal to s[X][Y] and $\left\lfloor \frac{f[i]}{q[i]} + \frac{1}{2} \right\rfloor$ is not equal to $\left\lfloor \frac{f[i]}{q[i]} \right\rfloor$,

$$f'[i] \leftarrow \left(\left\lfloor \frac{f[i]}{q[i]} + \frac{1}{2} \right\rfloor - 1 \right) \times q[i].$$

Here, X=i/t, Y=i mod t, and $\lfloor x \rfloor$ is the maximum integer which does not exceed x, and x mod y represents the remainder of x divided by y.

(Fourth Embodiment)

In the following, a fourth embodiment of the present invention will be described.

The fourth embodiment is a watermark reading process corresponding to the watermark embedding process of the third embodiment. According to the fourth embodiment, block data of watermarked digital data contents is obtained, and digital watermark data is read from frequency coefficients on the basis of transformation amount for each frequency band according to a manipulation method of the digital data contents.

Fig.12 is a flowchart showing the conventional digital watermark reading process based on quantization.

The digital watermark reading apparatus 20 obtains watermarked block data 205 by dividing watermarked digital data contents 105 into a plurality of blocks (m blocks in this example) in step 200. Then, a frequency coefficient matrix 215 is generated by performing an orthogonal transform on the watermarked block data 205 in step 210.

A pseudo-random sequence 225 is generated from input key data 22 in step 220. Then, a coefficient value (for each block) of the frequency coefficient matrix 215 is selected one by one using the pseudo-random sequence 225 so as to generate a watermarked frequency coefficient sequence 235 in step 230. Then, the watermark reading process is performed on the watermarked frequency sequence 235 so that a digital watermark sequence 245 is read in step 240. Finally, the original watermark data 107 is output by performing statistical processing on the digital watermark data sequence in step 250.

Next, the digital watermark reading process (step 240) will be described in detail with reference to a flowchart in Fig.13. The process for reading the digital watermark sequence from the watermarked frequency coefficient sequence {f'[i]} is shown in the following.

1. Following steps are carried out for all i($0 \leq i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n$) by using a frequency coefficient quantization width q.

2. The digital watermark sequence s[X][Y] is read from the frequency coefficient f'[i]. That is,

$$s[X][Y] = \left\lfloor \frac{f'[i]}{q} + \frac{1}{2} \right\rfloor \bmod 2 .$$

Here, $X = \left\lfloor \frac{i}{t} \right\rfloor$ $Y = i \bmod t$.

Fig.14 is a flowchart showing the watermark reading process of the fourth embodiment of the present invention. Here, as in the case of the third embodiment, let the watermark weight ratio sequence be $\{dv_0, v_1, \cdots, v_{N-1}\}$ $(0 \leqq v_u < M_u, 0 \leqq u < N)$, and let the watermark strength be Power (the watermark strength represents durability of digital watermark data against manipulations such as non-reversible compression to watermarked digital data contents.)

The process for reading the digital watermark data sequence from the watermarked frequency coefficient according to the fourth embodiment is carried out as follows.

1. For all i $(0 \le i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n)$, a following process is carried out.

2. A quantization width q[i] used when reading digital watermark data from the frequency coefficient f'[i] is obtained by $q[i] \leftarrow dv_0, v_1, \cdots, v_{N-1} \times Power$ by using an element $dv_0, v_1, \cdots, v_{N-1}$ of the watermark weight ratio sequence which corresponds to the band of frequency

coefficient f[i] (f[i] is a $(v_0, v_1, \cdots, v_{N-1})$ th component of the frequency coefficient matrices).

3. The digital watermark data sequence s[X][Y] is read from the watermarked frequency coefficient f'[i] in the following way.

$$s[X][Y] \leftarrow \left\lfloor \frac{f'[i]}{q[i]} + \frac{1}{2} \right\rfloor \bmod 2$$

Here, $X = \left\lfloor \frac{i}{t} \right\rfloor$ and $Y = i \bmod t$.

According to the above-mentioned third and fourth embodiment, the watermark embedding strength can be changed according to the frequency band. Specifically, the watermark embedding and reading method applicable for a manipulation method becomes possible. In the method, according to the amount of change of digital data contents from original data for each frequency band due to manipulation such as non-reversible compression, the watermark strength is raised to a band when the amount is large, and the watermark strength is reduced when the amount is small. Accordingly, both of the quality of watermarked digital data contents and the durability of digital watermark data can be improved at a time.

(Fifth Embodiment)

In the following, a fifth embodiment of the

present invention will be described. According to the fifth embodiment, a number of digital data contents (images, sounds and the like) are prepared and calculation of a watermark strength matrix is carried out for each frequency band.

A processing flow of the fifth embodiment is the same as that shown in Fig.10 basically. Here, the orthogonal transform process shown in Fig.10 is the same as an orthogonal transform process used for digital watermarking process. For example, if the orthogonal transform used for digital watermarking is discrete cosine transformation (DCT) for a 16×16 size, the DCT is used, and, if the transformation used for digital watermarking is fast Fourier transform (FFT) for an 128 ×128 size, the FFT is used.

Fig.15 is a flowchart showing the process of calculating the watermark strength matrix for each frequency band according to the fifth embodiment.

Here, let the frequency coefficient matrices be N, the size be $M_0 \times M_1 \cdots \times M_{N-1}$, and each of the components be $x0_{v0,v1,\cdots,vN-1}$, $xt_{v0,v1,\cdots,vN-1}$ $(0 \leqq v_u < M_u,\ 0 \leqq u < N)$. The process shown in Fig.16 is as follows.

1. For all i $(0 \leqq i < m)$, the following steps 2 and 3 are performed.
2. For all $(v_0, v_1, ..., v_{N-1}) = (0, 0, ..., 0) \sim (M_0, M_1, ..., M_{N-1})$, the

process of the following step 3 is performed.

3. $y^{(i)}_{v_0,v_1,\ldots,v_{N-1}} \leftarrow xo_{v_0,v_1,\ldots,v_{N-1}} - xt_{v_0,v_1,\ldots,v_{N-1}}$

4. For all $(v_0, v_1, \ldots, v_{N-1}) = (0, 0, \ldots, 0)\sim(M_0, M_1, \ldots, M_{N-1})$, the following steps 5 and 6 are performed.

5. $A_{v_0,v_1,\ldots,v_{N-1}} \leftarrow \dfrac{\sum_{i=0}^{m-1} y^{(i)}_{v_0,v_1,\ldots,v_{N-1}}}{m}$

6. $d_{v_0,v_1,\ldots,v_{N-1}} \leftarrow \sqrt{\dfrac{\sum_{i=0}^{m-1}\left(y^{(i)}_{v_0,v_1,\ldots,v_{N-1}} - A_{v_0,v_1,\ldots,v_{n-1}}\right)^2}{m}}$

According to the fifth embodiment, it becomes possible to set the watermark strength to a level that is suitable for each frequency band according to a manipulation method for digital data contents such as non-reversible compression. For example, if the watermark strength is Power and the distribution of the amount of change of each coefficient value of the frequency coefficients after a manipulation can be approximated by a Laplacian distribution, when digital watermark data is read from digital data contents on which an assumed manipulation is performed, the rate of bit reversal for the extracted digital watermark data can be made constant $e^{-\frac{Power}{\sqrt{2}}}$ regardless of the frequency band (e is the natural logarithm). It is the advantage of the present invention to be able to predict the rate of bit reversal with the constant formula. In

addition, according to the embodiment of the present invention, one of the problem of the conventional method that durability of embedded digital watermark data is varied according to the position of the frequency coefficient is solved. That is, the durability of the embedded digital watermark data is constant regardless of the position of the frequency coefficient (which is obvious from the above formula). The embodiment can be applied not only to the watermarking method based on quantization but also to a watermarking method based on the spread spectrum technique.

(Sixth Embodiment)

In the following, a sixth embodiment of the present invention will be described. According to the sixth embodiment, the digital watermark embedding process is carried out by utilizing the first embodiment and the third embodiment in combination. The watermark embedding process of the sixth embodiment will be described as a modification of the step 150 shown in Fig.6.

According to the sixth embodiment, the process for embedding digital watermark data in a frequency coefficient sequence {f[i]} is as follows.

1. For all i ($0 \leq i < \left\lfloor \frac{m}{n} \right\rfloor \cdot n$), the following is

performed.

2. A quantization width q[i] used when embedding digital watermark data into the frequency coefficient f[i] is obtained by q[i]$\leftarrow$d$v_0,v_1,\cdots,v_{N-1}$$\times$Power by using an element d$v_0,v_1,\cdots,v_{N-1}$ of the watermark weight ratio sequence which corresponds to the band of the frequency coefficient f[i].

3. The watermarked coefficient f'[i] is obtained from the frequency coefficient f[i] in the following way.

i) If $\left\lfloor \frac{f[i]}{q[i]}+\frac{1}{2} \right\rfloor \bmod 2$ is equal to s[X][Y],

f'[i]$\leftarrow$ $f[i]+\left(\left\lfloor \frac{f[i]}{q[i]}+\frac{1}{2} \right\rfloor \times q[i]-f[i]\right)\times e[i]$.

ii) If $\left\lfloor \frac{f[i]}{q[i]}+\frac{1}{2} \right\rfloor \bmod 2$ is not equal to s[X][Y] and $\left\lfloor \frac{f[i]}{q[i]}+\frac{1}{2} \right\rfloor$ is equal to $\left\lfloor \frac{f[i]}{q[i]} \right\rfloor$,

f'[i] $\leftarrow\left(\left\lfloor \frac{f[i]}{q[i]}+\frac{1}{2} \right\rfloor+\frac{e[i]+1}{2}\right)\times q[i]$.

iii) If $\left\lfloor \frac{f[i]}{q[i]}+\frac{1}{2} \right\rfloor \bmod 2$ is not equal to s[X][Y] and $\left\lfloor \frac{f[i]}{q[i]}+\frac{1}{2} \right\rfloor$ is not equal to $\left\lfloor \frac{f[i]}{q[i]} \right\rfloor$.

f'[i] $\leftarrow\left(\left\lfloor \frac{f[i]}{q[i]}+\frac{1}{2} \right\rfloor-\frac{e[i]+1}{2}\right)\times q[i]$.

Here, X=i/t, Y=i mod t, and $\lfloor x \rfloor$ is the maximum integer which does not exceed x, and x mod y represents the remainder of x divided by y.

According to the sixth embodiment, both of the quality of the watermarked digital data contents and the durability of digital watermark data can be further improved as compared with the first embodiment and the third embodiment applied separately. The watermark reading method shown in the fourth embodiment can be used as-is for a watermark reading method in the sixth embodiment.

The above-mentioned processes performed by the digital watermark reading apparatus and the digital watermark embedding apparatus according to the present invention can be constructed by a program which can be stored in a computer readable medium such as a disk unit, a floppy disk, CD-ROM and the like. Then, by installing the program into a computer from the medium, the present invention can be easily realized.

[Advantages of the Invention]

As described above, according to the present invention, it is possible to change the ratio of the changed amount of the frequency component at the time of embedding the digital watermark with every frequency band, and/or to improve quality of watermarked digital

data contents and to improve durability of digital watermark data against media processing of the watermarked digital data contents.

[Brief Description of the Drawings]

Fig.1 is a diagram showing an overview of an input/output relationship of the digital watermark embedding processing apparatus;

Fig.2 is a diagram showing an overview of an input/output relationship of the digital watermark reading processing apparatus;

Fig.3 is a flowchart showing a conventional digital watermark embedding processing;

Fig.4 is a detailed flowchart showing an important part of the conventional digital watermark embedding processing;

Fig.5 is a schematic diagram showing a conventional digital watermark embedding processing;

Fig.6 is an overall flowchart showing a digital watermark embedding processing of embodiment 1 of the present invention;

Fig.7 is a detailed flowchart showing an important part of the digital watermark embedding processing of embodiment 1;

Fig.8 is schematic diagram showing the digital watermark embedding processing of embodiment 1;

Fig.9 is a processing flowchart of data complexity calculation of embodiment 2 of the present invention;

Fig.10 is a processing flowchart of the digital watermark weight ratio sequence used in embodiments 3 and 4 of the present invention;

Fig.11 is a detailed flowchart of an important part of the digital watermark embedding processing of embodiment 3 of the present invention;

Fig. 12 is an overall flowchart of the conventional digital watermark reading processing;

Fig. 13 is a detailed flowchart of the important part of the conventional digital watermark reading processing;

Fig. 14 is a detailed flowchart of the important part of the digital watermark reading processing of embodiment 4 of the present invention;

Fig. 15 is a detailed flowchart of the digital watermark strength matrix calculation of embodiment 5 of the present invention.

[Description of the Reference Numbers]

10 digital watermark embedding apparatus

11 data contents

12 key data

13 digital watermark data

14 watermark data contents

20 digital watermark reading processing apparatus

21 watermark data contents

22 key data

23 digital watermark data

[Name of the Document] Abstract

[Abstract]

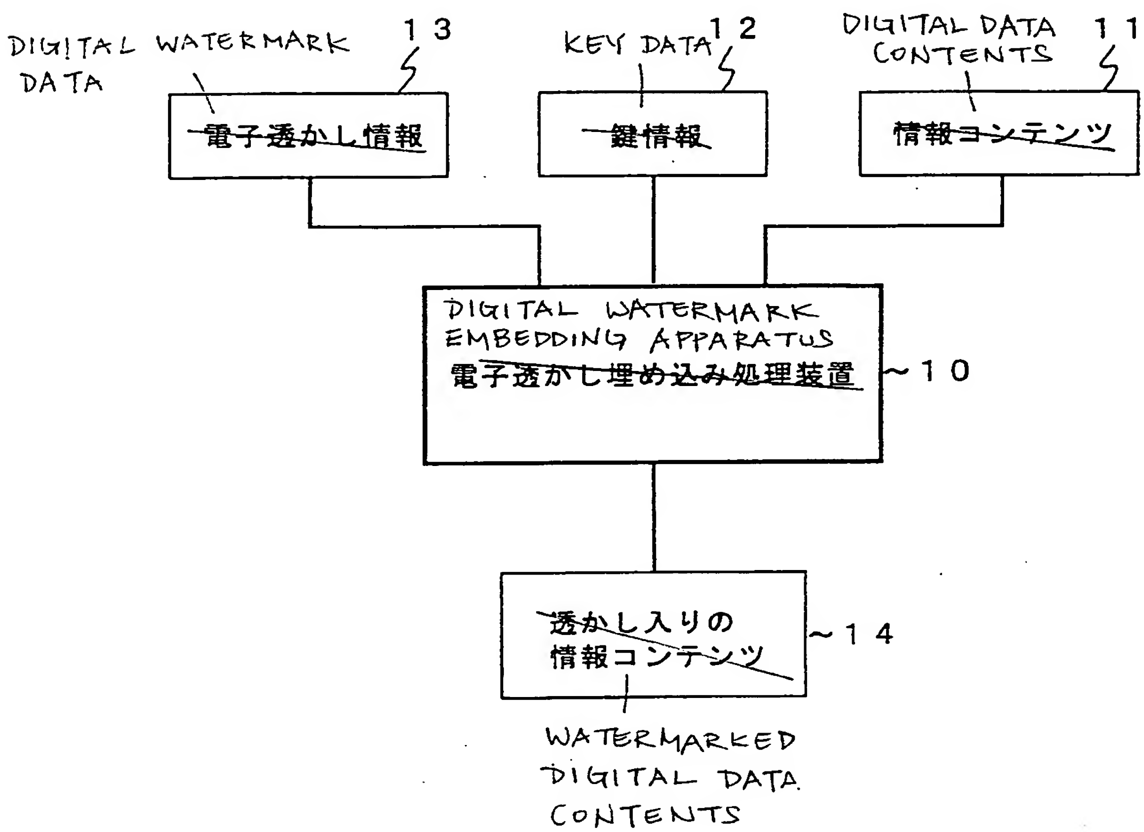
[Object] Object of the present invention to improve quality of watermarked digital data contents and to improve durability of digital watermark data against media processing of the watermarked digital data contents.

[Solution Means] The present invention calculates a complexity of data based on human perception of each partial data in a process for embedding the digital watermark respectively to the partial data of the data contents, and changes the changed amount of the partial data according to its values. Watermark strength matrix is prepared in every frequency range, and together with this and the digital watermark strength being multiplied will be the frequency component changing amount when actually embedding the digital watermark.

[Selected Figure] Fig. 6

~~【書類名】~~　図面　[Name of the Document] DRAWING

~~【図１】~~ FIG. 1



~~【図２】~~ FIG.2

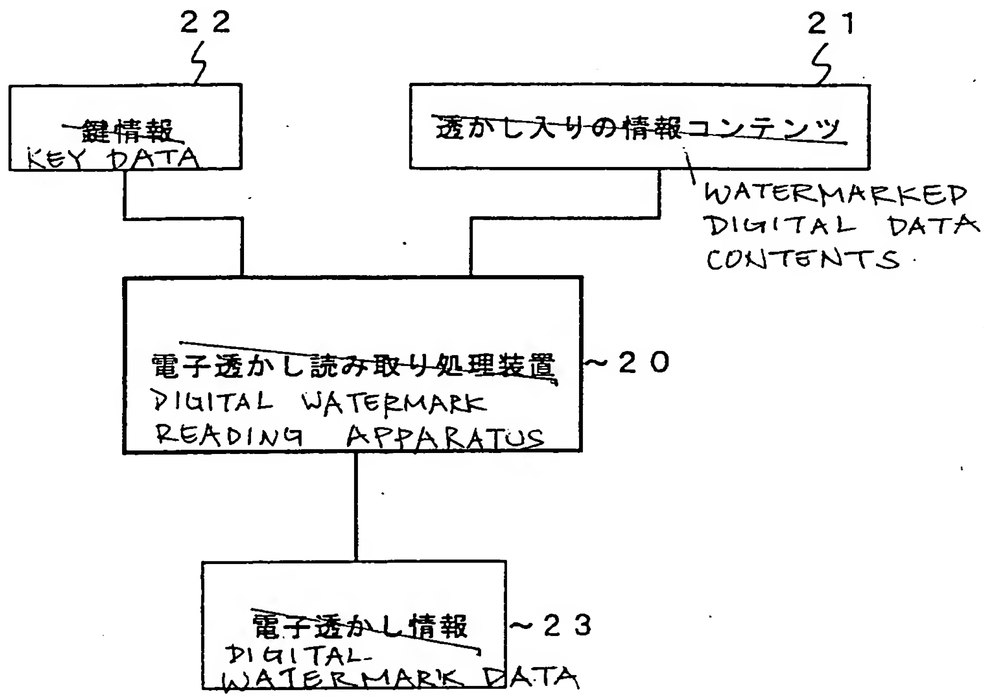
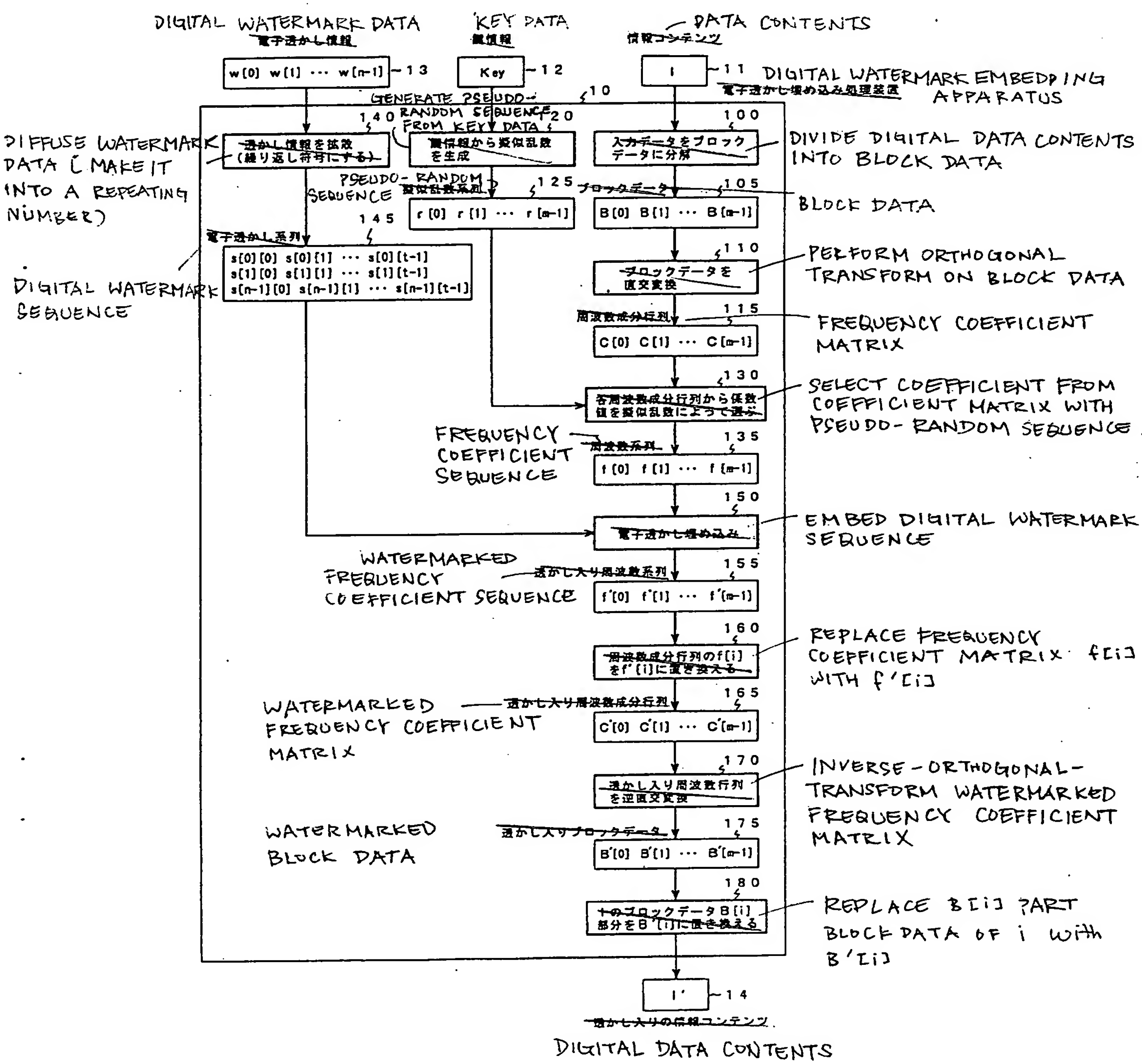

22
21
~~鍵情報~~
KEY DATA
~~透かし入りの情報コンテンツ~~
WATERMARKED DIGITAL DATA CONTENTS
~~電子透かし読み取り処理装置~~
DIGITAL WATERMARK READING APPARATUS
～２０
~~電子透かし情報~~
DIGITAL WATERMARK DATA
～２３

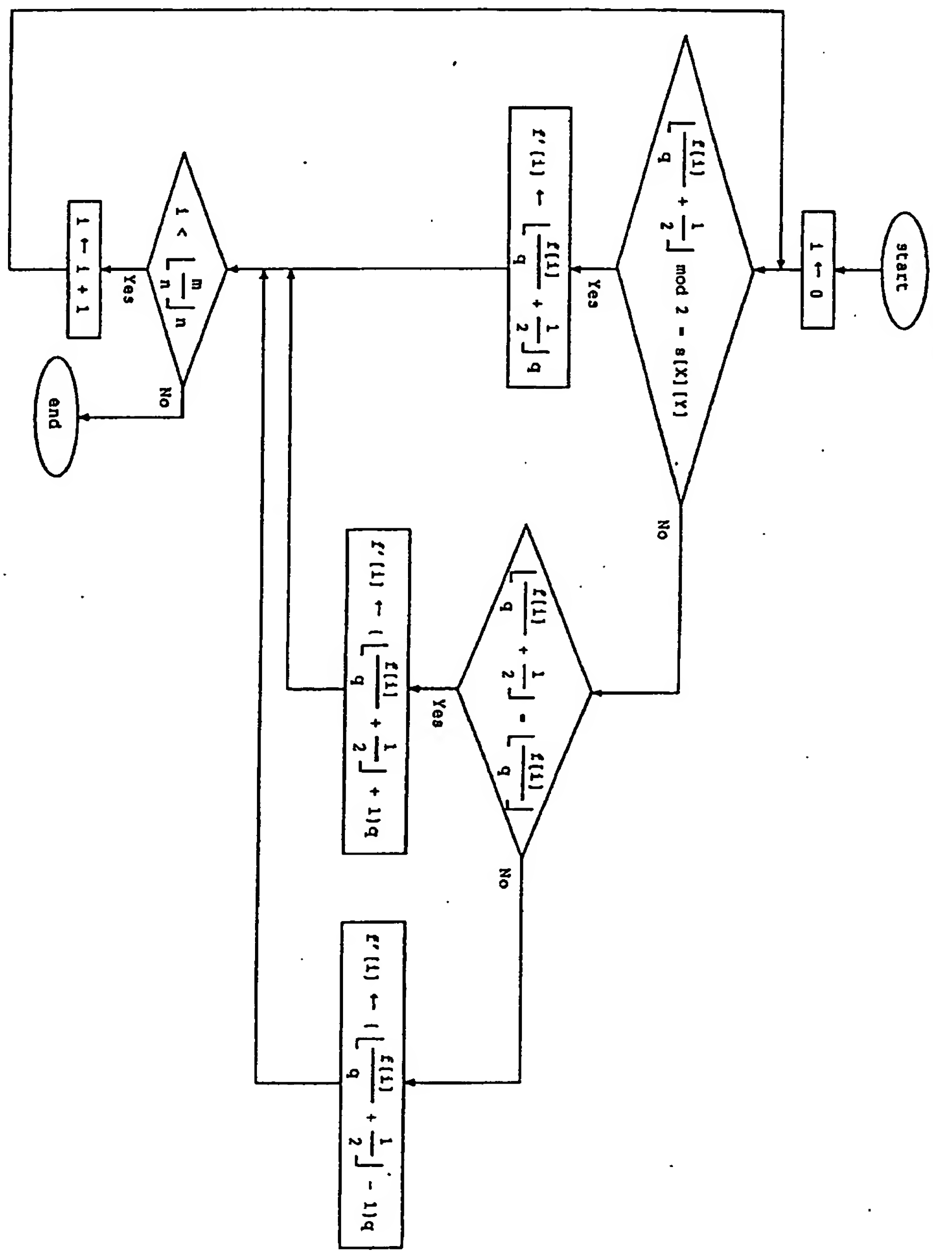
FIG.3 【図3】

A FLOWCHART SHOWING THE DIGITAL WATERMARK EMBEDDING PROCESS ACCORDING TO THE CONVENTIONAL TECHNIQUE

~~従来の電子透かし埋め込み処理フロー~~



~~【図4】~~ FIG.4



~~従来の電子透かし埋め込み処理フローチャート~~

A FLOWCHART SHOWING THE DIGITAL WATERMARK EMBEDDING PROCESS ACCORDING TO THE CONVENTIONAL TECHNIQUE

~~【図５】~~ FIG.5

A CONCEPTUAL DIAGRAM OF THE DIGITAL WATERMARK EMBEDDING PROCESS ACCORDING TO THE CONVENTIONAL TECHNIQUE

~~従来の電子透かし埋め込み処理概念~~

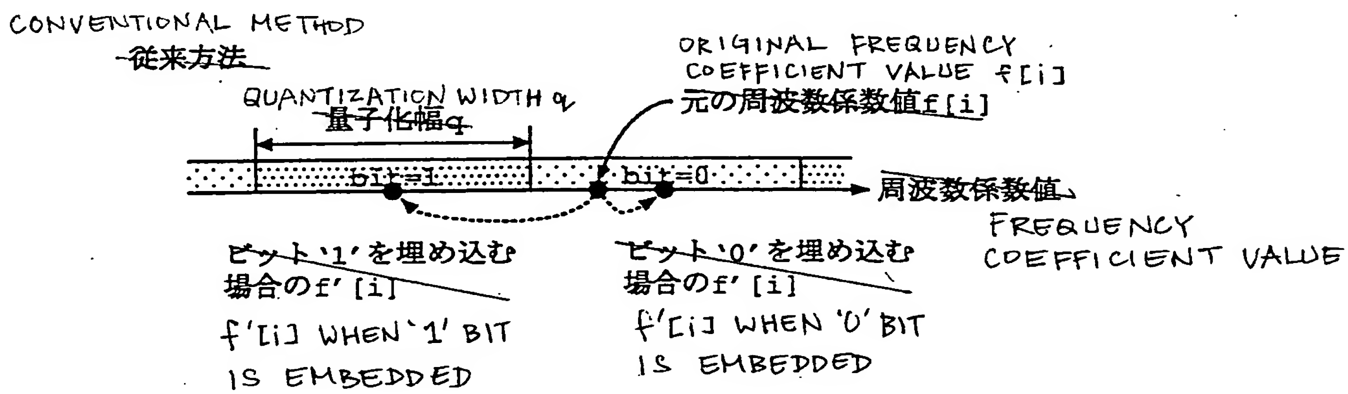
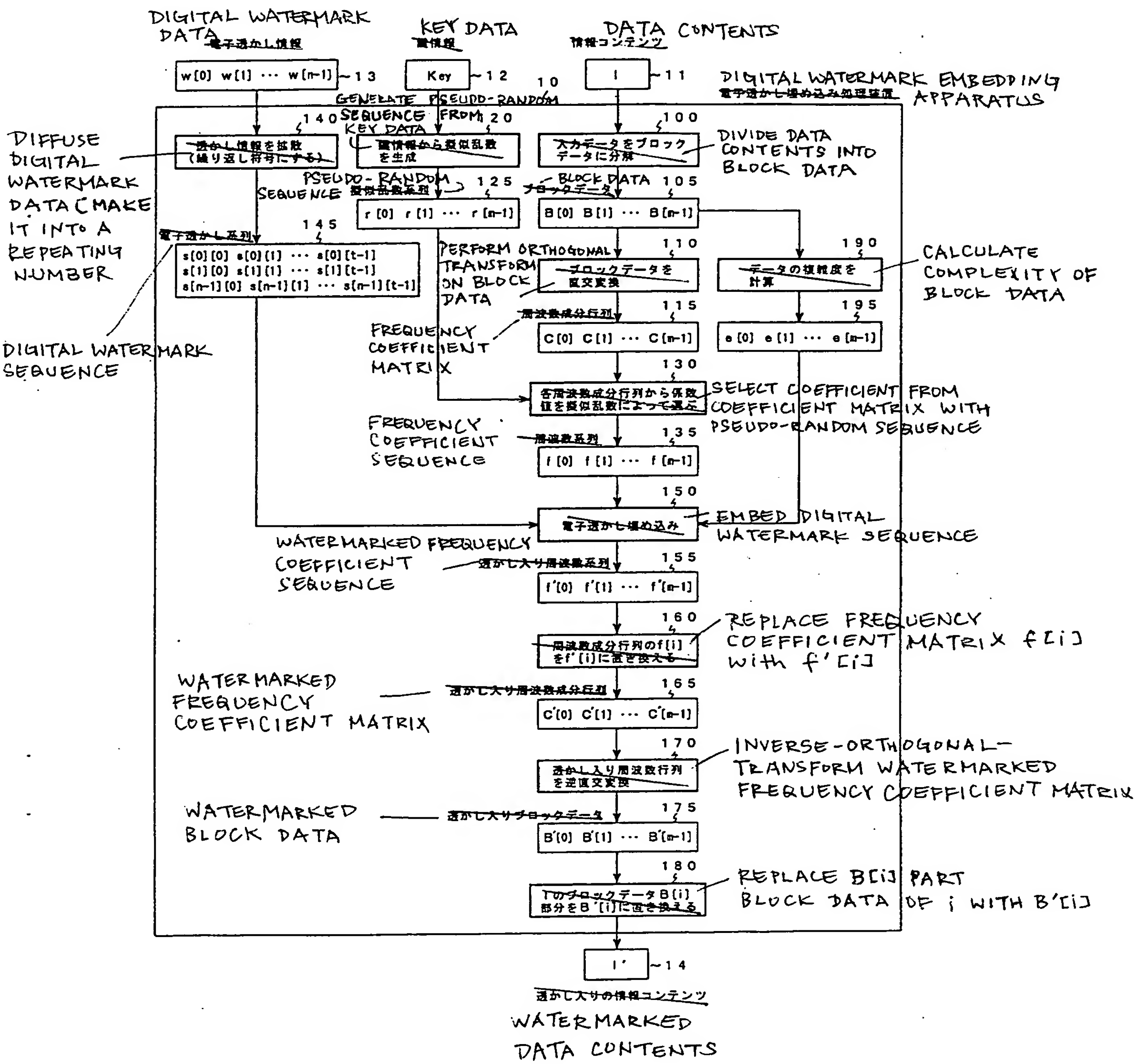
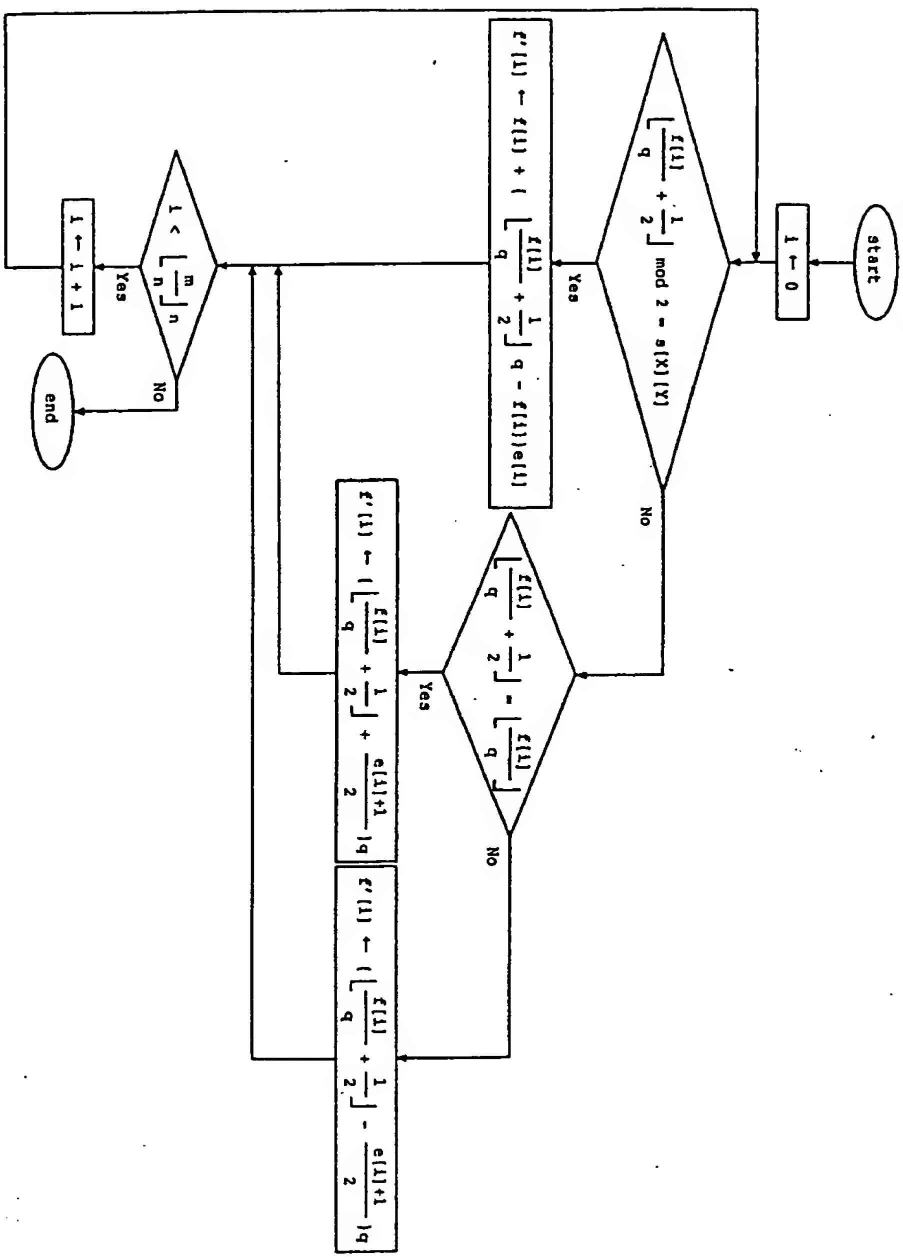


FIG. 6【図6】

A FLOWCHART ACCORDING TO A FIRST EMBODIMENT
~~実施例１の処理フロー~~



~~【図７】~~FIG. 10

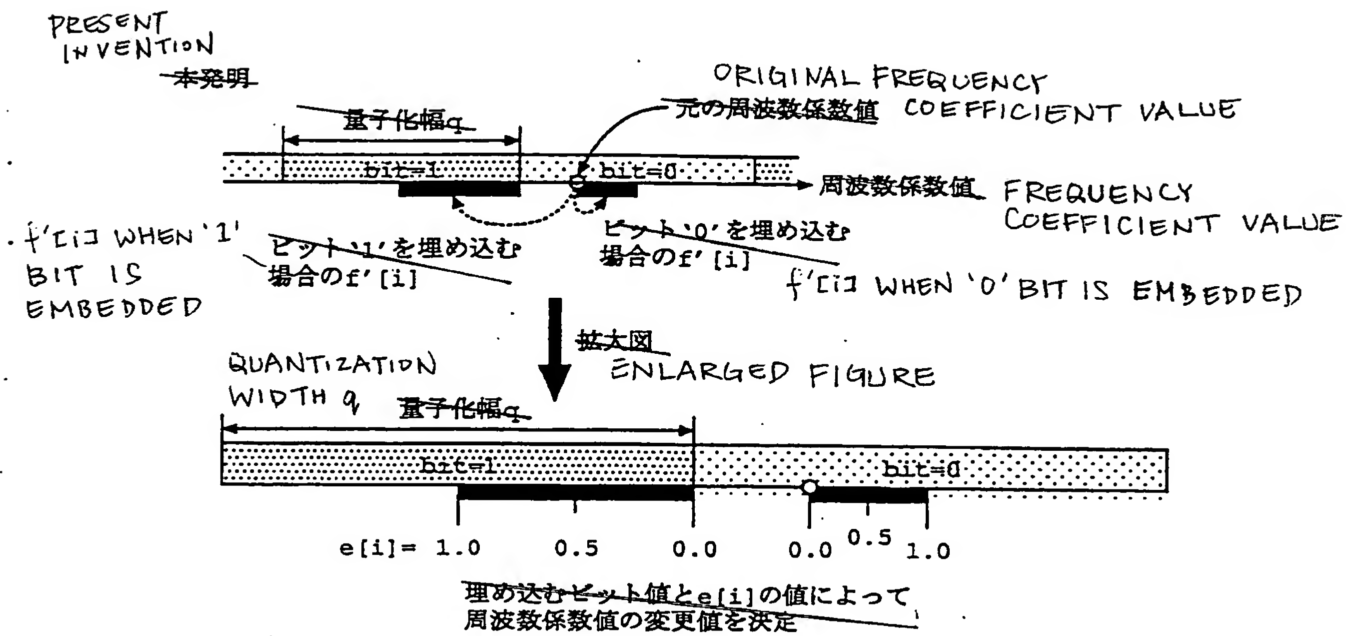


A FLOWCHART OF THE DIGITAL WATERMARK EMBEDDING PROCESS ACCORDING TO THE FIRST EMBODIMENT ~~実施例１の電子透かし埋め込み処理フローチャート~~

【図8】 FIG.8

A CONCEPTUAL DIAGRAM OF THE FIRST EMBODIMENT

~~実施例１の処理概念~~

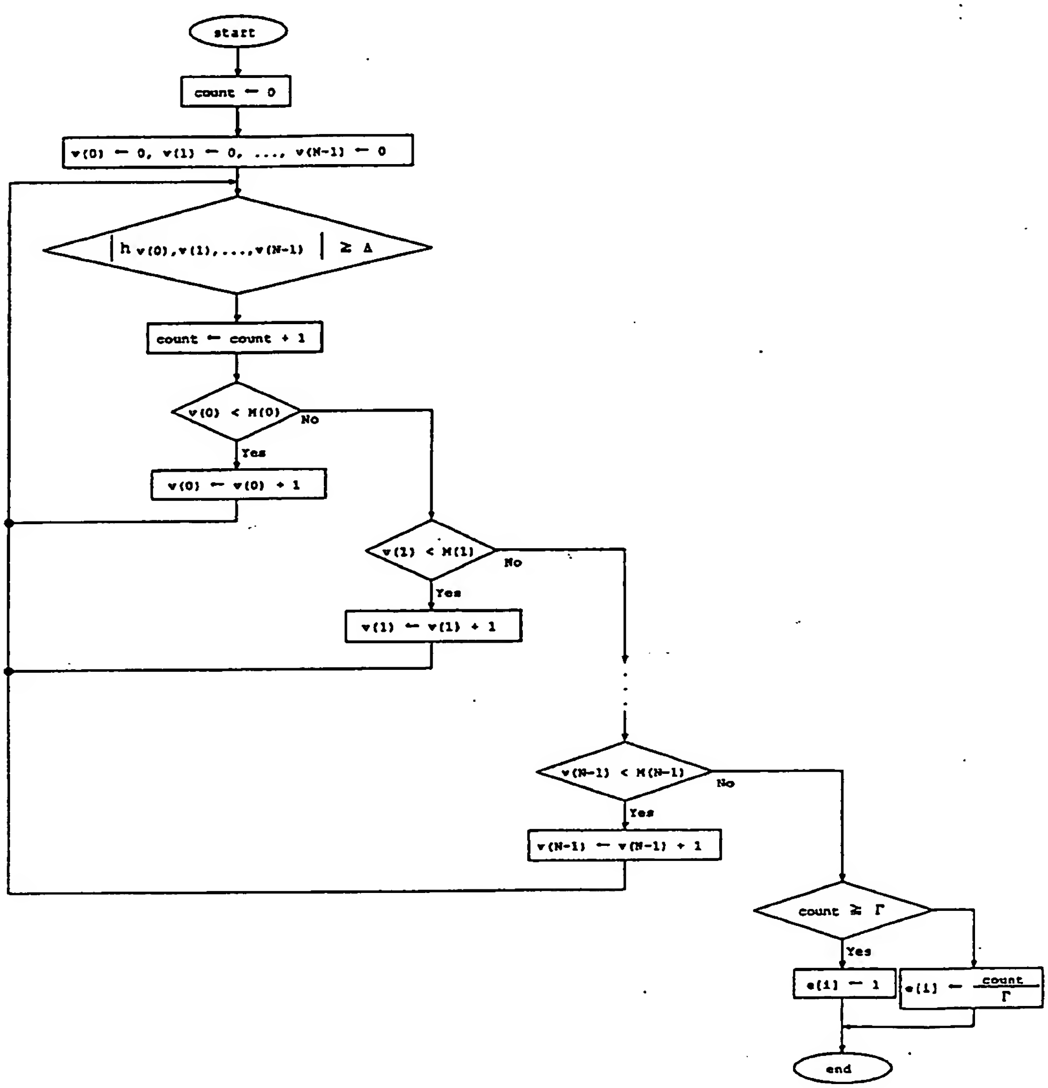


DETERMINE A VALUE OF THE FREQUENCY COEFFICIENT ACCORDING TO A BIT VAUE TO BE EMBEDDED AND A VALUE OF e[i]

FIG.9 ~~【図9】~~

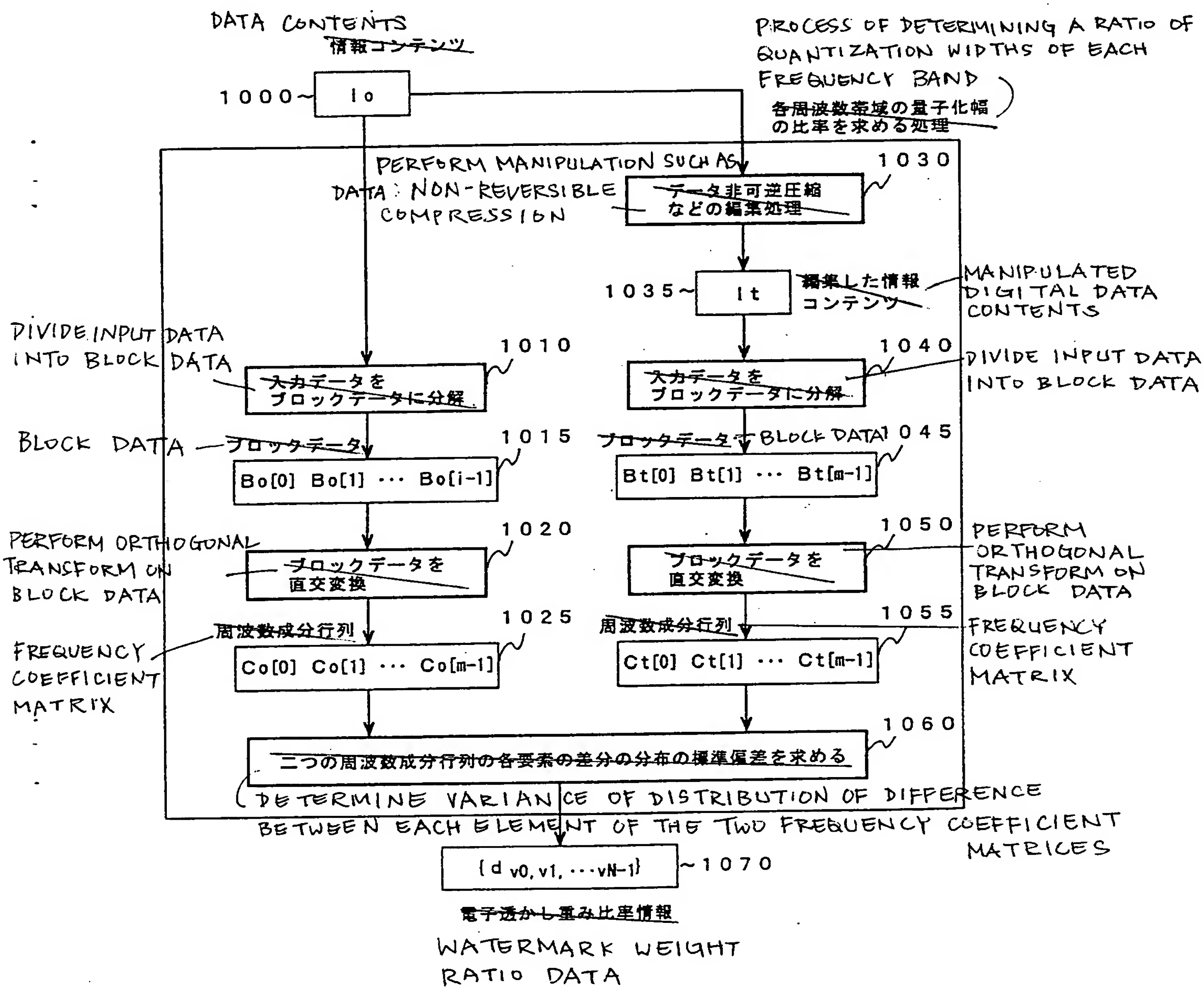
~~実施例２のデータ複雑度計算処理フローチャート~~

A FLOWCHART OF A PROCESS FOR CALCULATING A DATA COMPLEXITY ACCORDING TO THE SECOND EMBODIMENT

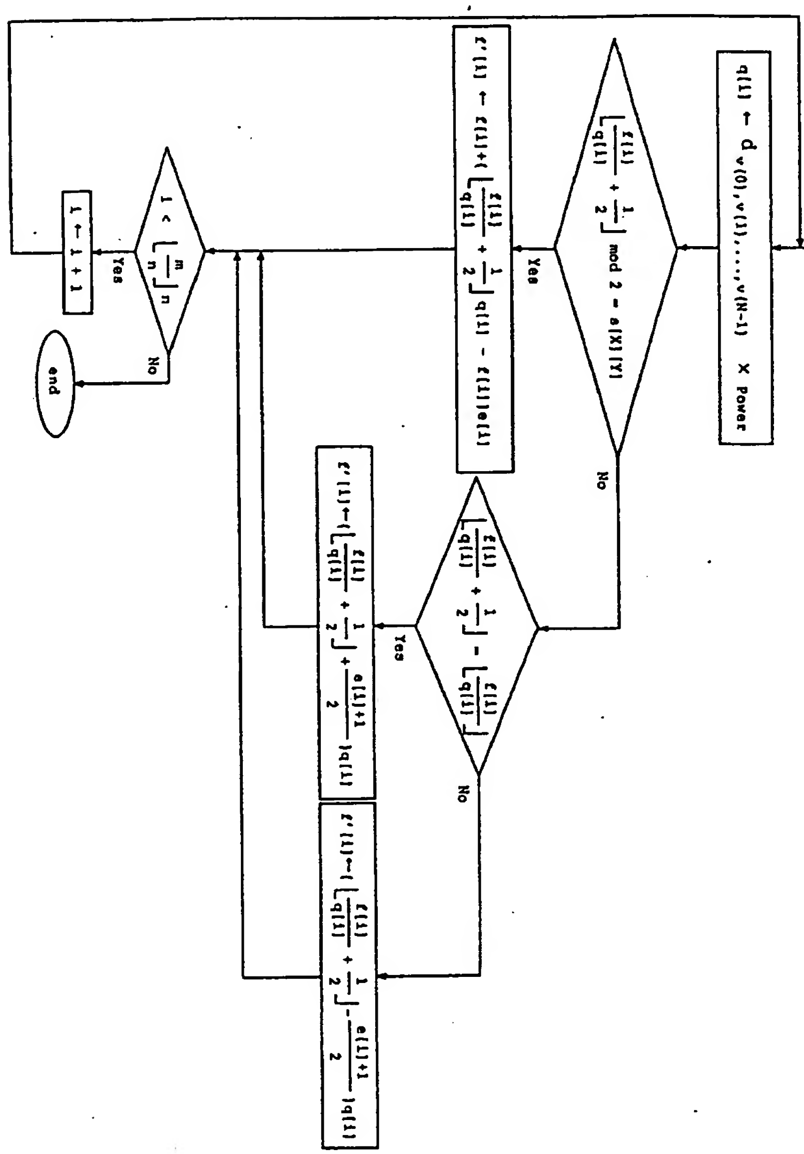


~~【図１０】~~
FIG.10　A FLOWCHART OF A PROCESS FOR OBTAINING A WATERMARK WEIGHT RATIO DATA

~~電子透かし重み比率系列を求める処理フロー~~



【図~~１１~~】FIG. 11

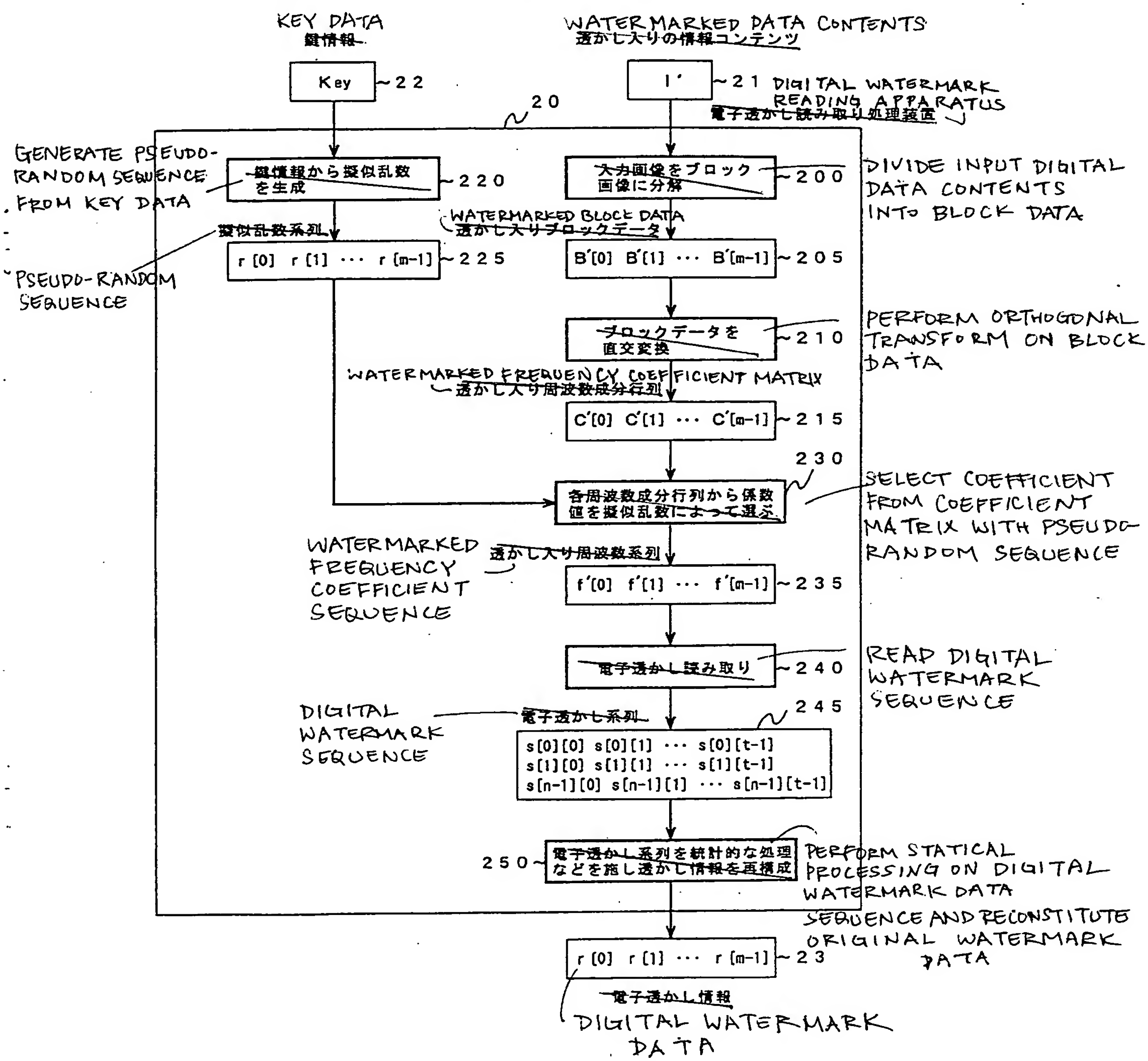


A FLOWCHART OF THE DIGITAL WATERMARK EMBEDDING PROCESS ACCORDING TO A THIRD EMBODIMENT

~~実施例３の~~電子透かし埋め込み処理~~フローチャート~~

FIG.12 ~~【図１２】~~ A FLOWCHART SHOWING A DIGITAL WATERMARK READING PROESSS ACCORDING TO THE CONVENTIONAL TECHNIQUE.

~~従来の電子透かし読み取り処理フロー~~



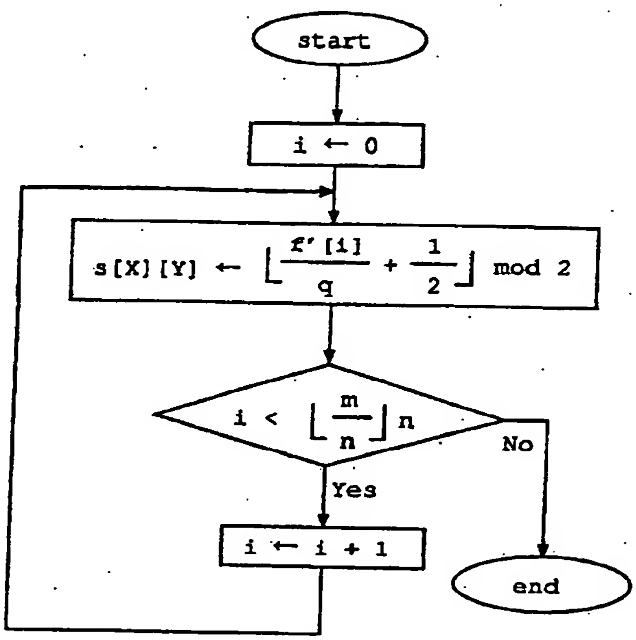
【図~~１３~~】

FIG: 13

A FLOWCHART OF THE CONVENTIONAL DIGITAL WATERMARK READING PROCESS

~~従来の電子透かし~~

~~読み取り処理フローチャート~~



【~~図１４~~】FIG. 14

A FLOW CHART OF THE DIGITAL WATERMARK READING PROCESS OF A FOURTH EMBODIMENT

~~実施例４の電子透かし読み取り処理フローチャート~~

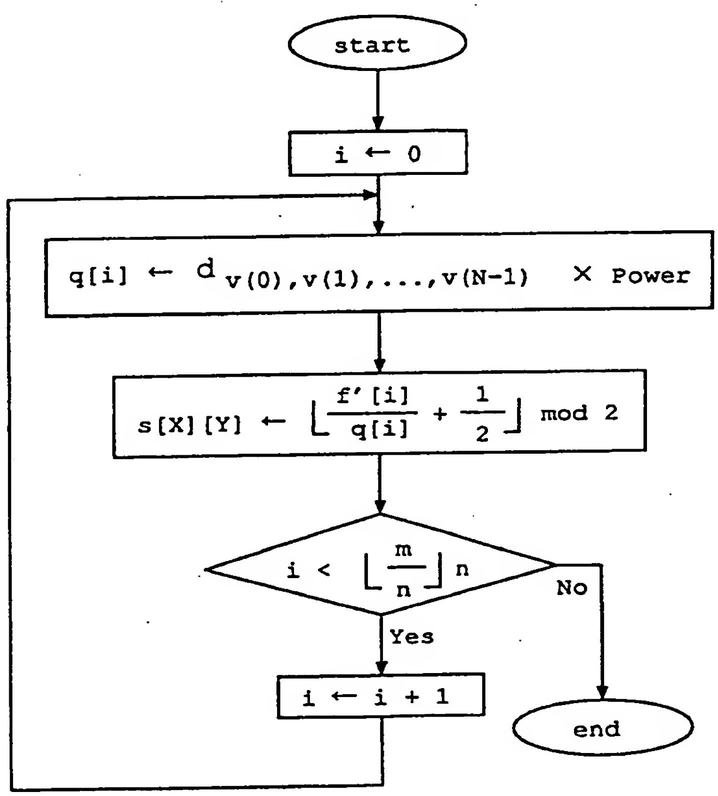


FIG. 15 ~~【図１５】~~ A FLOWCHART SHOWING A PROCESS OF CALCULATING A WATERMARK STRENGTH MATRIX ACCORDING TO A FIFTH EMBODIMENT

~~実施例５の周波数帯域毎の電子透かし~~
強度マトリックス計算処理~~フローチャート~~